PATENT SPECIFICATION

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DRAWINGS ATTACHED

1 262 182

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(54) IMPROVEMENTS IN OR RELATING TO TURBINE ROTOR BLADES

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The following corrections were allowed under Section 76 on 19 July 1972:-

Page 1, *insert* Inventors:

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THE PATENT OFFICE
4 August 1972

R 11097/13

can be most effectively used in the last stages of steam and gas turbines.

Last stage blades in turbine rotors may have a length exceeding 800 mm. During operation these blades are exposed to high stresses as the cross-sectional areas of each blade is strictly limited. The limitations are connected with the blade weight and its aerodynamic resistances, both of which should be as small as possible. For ensuring uniform distribution of such stresses, the blade cross-sections are given different shapes and areas along its length. The blade at its root is twisted through a large angle and has a large sectional area; but the further the location of the cross-section from the blade root, the lower is the angle of twist, so that the cross-sectional area can become relatively small. However, maximum bending stresses in the blade generated by the working medium pressure and the maximum resultant tensile stresses due to the effect of the centrifugal force, act on the slightly twisted tip portion of the blade where the cross-section is relatively small and, hence, the moments of resistance of these sections are also small.

To increase the moments of resistance to the required values, the blade is usually twisted at its tip more than it is necessary for the required conditions of operation. The blade thus has a shape differing from the optimum one from the aerodynamic aspect, thus causing comparatively high energy losses as the working medium flows over the blade.

with the invention, the area of maximum bending stresses is shifted from the edges where a dangerous concentration of stresses exists to the wave-shaped bulge.

In the preferred embodiment of the blade design, the crest point of the wave-shaped bulge should be located at distance from the leading edge, being determined by formula:

$$l=(0.5 \text{ to } 0.6)\ B \sin \beta$$

where B is the length of the profile chord,

β is the angle in the plane of the cross-section of the blade along a given radius between the tangent to the circumferences of the leading and trailing edges of the profile of the blade and the plane perpendicular to the axis of the rotor rotation.

The maximum thickness y of the blade profile at the crest point of the wave-shaped bulge is determined by formula:

$$y=(0.2 \text{ to } 0.3)\ B \sin \beta$$

The wave-shaped bulge is provided at the positions determined by the formulae hereinbefore set forth, firstly, to shift the zone of maximum bending stresses from the edges of each profile to the crest of the wave-shaped bulge, secondly, to decrease the chord of the profile, preserving constant, at the same time, the cross-sectional area of the blade, and, thirdly, to increase the moment of resistance of the profile.

SEE CORRECTION SLIP ATTACHED

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(54) IMPROVEMENTS IN OR RELATING TO TURBINE ROTOR BLADES

(71) We, MOSKOVSKY ORDENA LENINA ENERGETICHESKY INSTITUT, a corporation organised and existing under the laws of the Union of Soviet Socialist Republics, of 14 Krasnokazarmennaya, ul., Moscow, Union of Soviet Socialist Republics, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to the rotor blades of steam and gas turbines.

Blades in accordance with the invention can be most effectively used in the last stages of steam and gas turbines.

Last stage blades in turbine rotors may have a length exceeding 800 mm. During operation these blades are exposed to high stresses as the cross-sectional areas of each blade is strictly limited. The limitations are connected with the blade weight and its aerodynamic resistances, both of which should be as small as possible. For ensuring uniform distribution of such stresses, the blade cross-sections are given different shapes and areas along its length. The blade at its root is twisted through a large angle and has a large sectional area; but the further the location of the cross-section from the blade root, the lower is the angle of twist, so that the cross-sectional area can become relatively small. However, maximum bending stresses in the blade generated by the working medium pressure and the maximum resultant tensile stresses due to the effect of the centrifugal force, act on the slightly twisted tip portion of the blade where the cross-section is relatively small and, hence, the moments of resistance of these sections are also small.

To increase the moments of resistance to the required values, the blade is usually twisted at its tip more than it is necessary for the required conditions of operation. The blade thus has a shape differing from the optimum one from the aerodynamic aspect, thus causing comparatively high energy losses as the working medium flows over the blade.

According to the present invention there is provided a rotor blade of a steam or gas turbine, comprising a shank, a profiled part with a lengthwise varying cross-section, and with a mainly concave pressure face, a single wave-shaped bulge provided on said pressure face, the crest point of this bulge being located between the leading edge and the middle of said face of the profile, and considered from leading to the trailing edge, said blade having along a part only of its length a concave portion, a convex portion and a further concave portion.

In a blade manufactured in accordance with the invention, the area of maximum bending stresses is shifted from the edges where a dangerous concentration of stresses exists to the wave-shaped bulge.

In the preferred embodiment of the blade design, the crest point of the wave-shaped bulge should be located at distance from the leading edge, being determined by formula:

$$l = (0.5 \text{ to } 0.6)\ B \sin \beta$$

where B is the length of the profile chord,

β is the angle in the plane of the cross-section of the blade along a given radius between the tangent to the circumferences of the leading and trailing edges of the profile of the blade and the plane perpendicular to the axis of the rotor rotation.

The maximum thickness y of the blade profile at the crest point of the wave-shaped bulge is determined by formula:

$$y = (0.2 \text{ to } 0.3)\ B \sin \beta$$

The wave-shaped bulge is provided at the positions determined by the formulae hereinbefore set forth, firstly, to shift the zone of maximum bending stresses from the edges of each profile to the crest of the wave-shaped bulge, secondly, to decrease the chord of the profile, preserving constant, at the same time, the cross-sectional area of the blade, and, thirdly, to increase the moment of resistance of the profile.

SEE CORRECTION SLIP ATTACHED

The above-mentioned characteristic features of the profile make it possible, firstly, to raise the reliability of the blade, secondly, to decrease by 20—40% the bending stresses in the most heavily loaded portion of the blade in comparison with blades with profiles having no bulge, or, while preserving the same value of the stresses, to decrease the cross-sectional area, which is of great importance for relatively long and highly loaded blades of the last stages of turbines, and, thirdly, to simply the designing of blades due to the possibility of varying the coordinates of the centre of gravity of each separate cross-section of the blade by changing the distance between the leading edge of the blade and the wave-shaped bulge.

An embodiment of a blade according to the invention will now be described, by way of example, with reference to the accompanying drawing in which:—

Fig. 1 illustrates the profile of the blade at mid-length according to the invention; and

Fig. 2 is a top view of the blade according to the invention showing in broken lines the profiles at various positions along the blade length.

Profile 1 of the blade (Fig. 1) with chord B has a maximum thickness y at a wave-shaped bulge 2 formed on the profile concave face *ad*, i.e. the pressure face. The crest point m of the bulge 2 is located between the leading edge and the middle of said face.

The profile concave face is formed of the following sections which extend over a part only of the length of the blade:

—section *ab*, being a concave curve,
—section *bc*, which is a convex curve,
and section *cd*, being a concave curve.

These are smooth curves with smooth conjugations (points b and c).

The rotor blade (Fig. 2) has a varying profile along its length. The most characteristic cross-sections of this blade are limited by the following profiles: profile 3 (broken line) at the blade root; profile 4 (broken line) located at 1/4 of the blade length from the blade root; profile 1 (broken line) at mid-length of the blade, as shown in Fig. 1; profile 5 (broken line) spaced 3/4 of the blade length away from the blade root; profile 6 at the blade tip.

Profiles 4, 1 and 5 have the wave-shaped bulge on their concave face. Shank 7 is provided to secure the blade to the rotor hub.

Position of the peak point m (Fig. 1) of the profile bulge is determined by formula:

$$l=(0.5 \text{ to } 0.6)\ B \sin \beta$$

The maximum profile thickness y is determined by formula:

$$y=(0.2 \text{ to } 0.3)\ B \sin \beta$$

where B and β have the significations given hereinbefore.

WHAT WE CLAIM IS:—

1. A rotor blade of a steam or gas turbine, comprising a shank, a profiled part with a lengthwise varying cross-section, and with a mainly concave pressure face, a single wave-shaped bulge provided on said pressure face, the crest point of this bulge being located between the leading edge and the middle of said face of the profile, and considered from leading to trailing edge, said blade having along a part only of its length a concave portion, a convex portion and a further concave portion.

2. A blade as claimed in claim 1, wherein the crest point of the bulge is located at a distance l from the blade leading edge, said distance being determined by formula

$$l=(0.5 \text{ to } 0.6)\ B \sin \beta$$

where B is the length of the profile chord;

β is the angle in the plane of the cross-section of the blade along a given radius between the tangent to the circumferences of the leading and trailing edges of the profile of the blade and the plane perpendicular to the axis of the rotor rotation.

3. A blade as claimed in claim 1 or claim 2, wherein the maximum profile thickness y at the bulge is determined by formula

$$y=(0.2 \text{ to } 0.3)\ B \sin \beta$$

where B is the length of the profile chord;

β is the angle in the plane of the cross-section of the blade along a given radius between the tangent to the circumferences of the leading and trailing edges of the profile of the blade and the plane perpendicular to the axis of the rotor rotation.

4. A rotor blade of a steam or gas turbine made substantially as hereinbefore described and as illustrated in the accompanying drawings.

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1262182 COMPLETE SPECIFICATION
1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

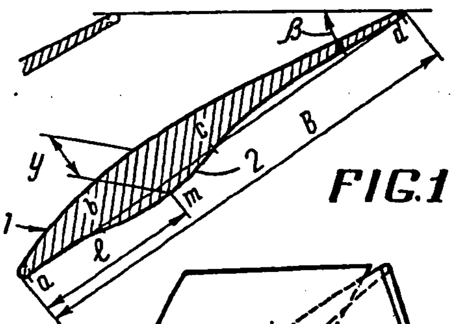

FIG.1

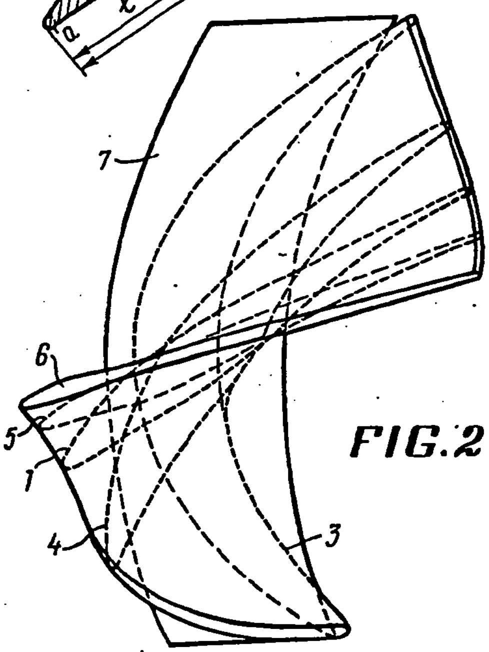

FIG.2